

Analysis of O₂ Column Abundances using A-Band High Resolution
Solar Absorption Spectroscopy at Table Mountain, CA

Z. Yang¹, P. Wennberg¹, G. Toon², L. Brown², C. Miller³, T. Pongetti²,
R. Cageao² and S. Sander^{2,1}

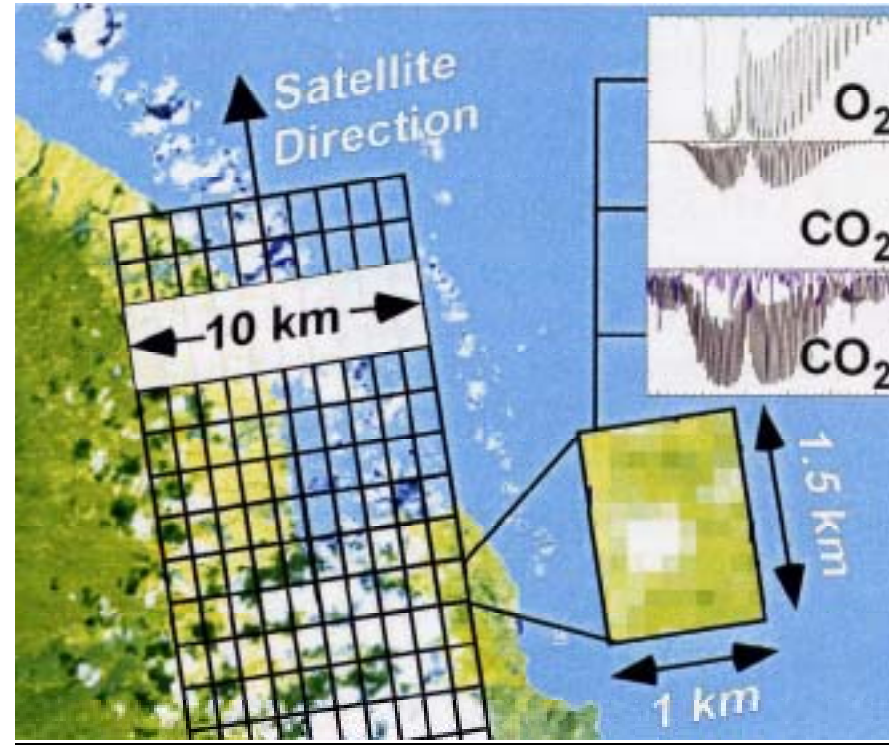
¹Division of Geological and Planetary Science
California Institute of Technology
Pasadena, CA 91125

²Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

³ Haverford College,
Philadelphia, PA

BACKGROUND AND OBJECTIVES

- ESSP/Orbiting Carbon Observatory (OCO) measurement requirement is CO_2 column abundance with 0.3% precision.
- Ground-based FT spectroscopy plays an important role in calibration and validation of OCO.
- FTUVS measures O_2 and CO_2 in the same near-IR bands as OCO. Diurnal measurements will establish the feasibility of achieving 0.3% precision.
- O_2 is the first objective because its column abundance is known.
- Provide a check on A-band spectroscopic parameters that will be useful for other instruments including SAGE III, SCIAMACHY



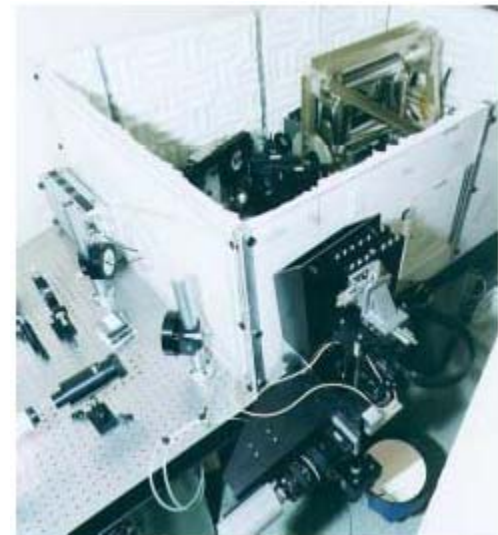
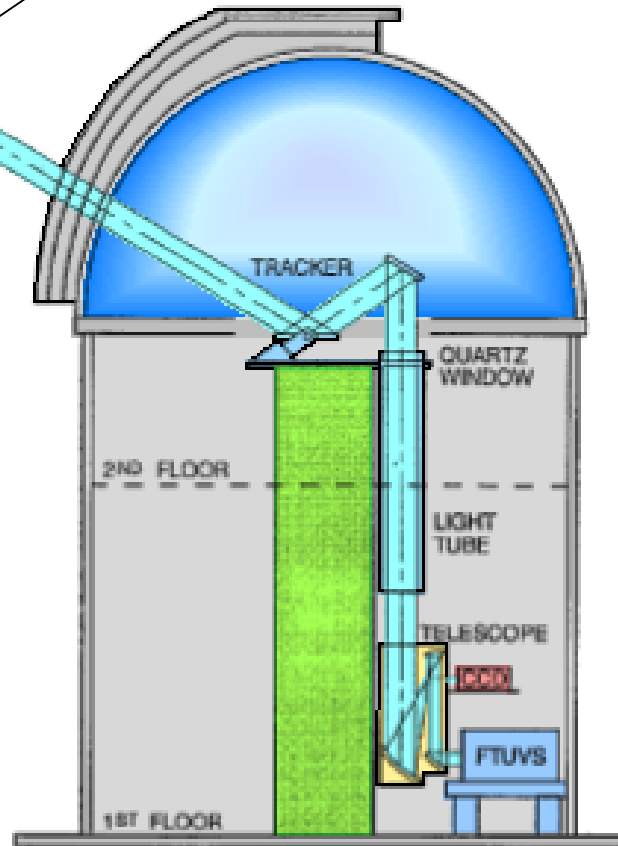
OCO IFOV and spectral bands

Table mountain dome and instruments



stratosphere

troposphere



Atmospheric Measurements

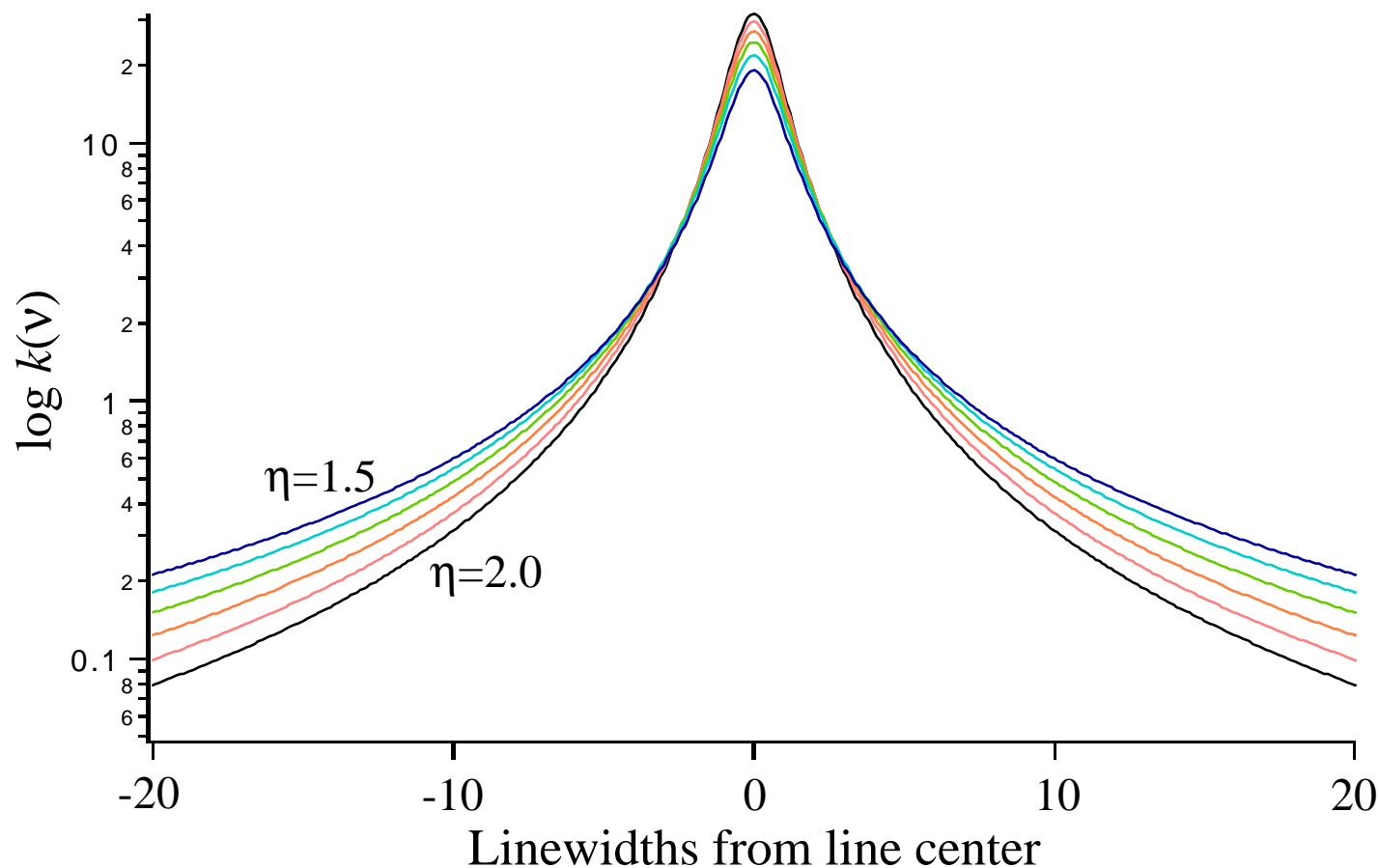
- O₂ A-band data acquired 3/24/03 - 4/11/03 using FTUVS/TMF (12days)
- Air mass range 7.7 (morning) - 7.6 (afternoon)
- Spectra every 30 min (A/M < 3), continuously (A/M > 3)
- Spectral range: 12,100 - 15100 cm⁻¹, resolution 0.056 cm⁻¹
- Noontime SNR: 1300:1

Forward Model Configuration

- O₂ line positions and strengths from Brown and Plymate (2000)
- Update B&P's broadening coefficients with high N' results of Yang et al.
- Super-Lorentz lineshape of Hirono and Nakazawa (1982) to model continuum
- Temperature profile:
 - 2.3 < z < 5 km: best fit to spectrum
 - z > 5 km: profile from assimilation model (NCEP/NCAR reanalysis)
- Atmospheric overburden calculated from measured surface pressure and assumption of hydrostatic equilibrium
- Water vapor is not explicitly retrieved; climatological water vapor is used as a first-order correction for the column-average O₂ mixing ratio.
- O₂ isotopomers are retrieved separately.

Lorentz:
$$k(\nu) = \frac{S}{\pi} \frac{\gamma}{(\nu - \nu_0)^2 + \gamma^2}$$

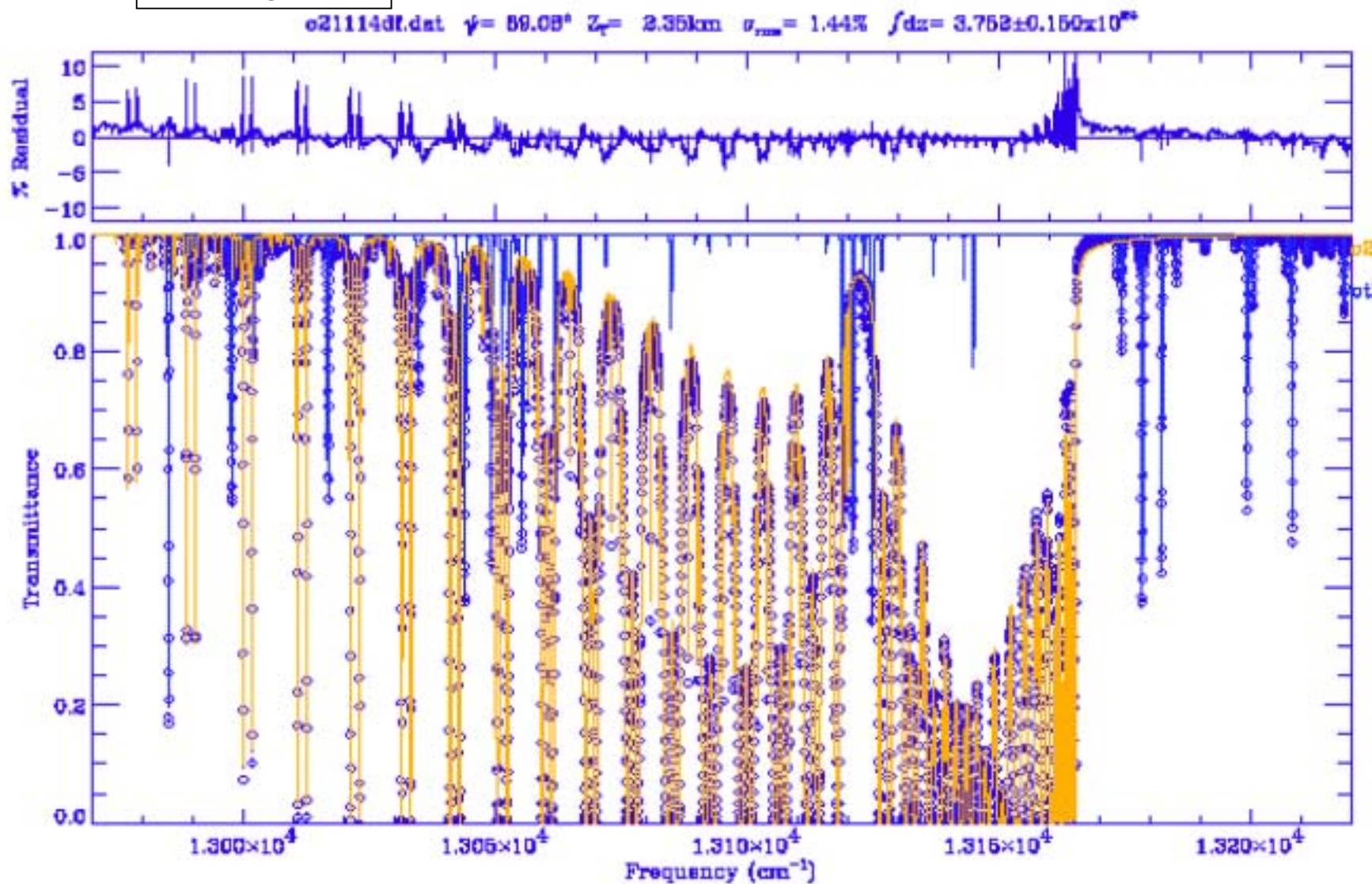
Super-Lorentz:
$$k(\nu) = \frac{S}{\pi^{1/2}} \frac{S\Gamma(\eta/2)}{\Gamma((\eta-1)/2)} \frac{\gamma^{\eta-1}}{\{(\nu - \nu_0)^2 + \gamma^2\}^{\eta/2}}, \quad (1 < \eta \leq 2)$$



Line Strengths
for high N'

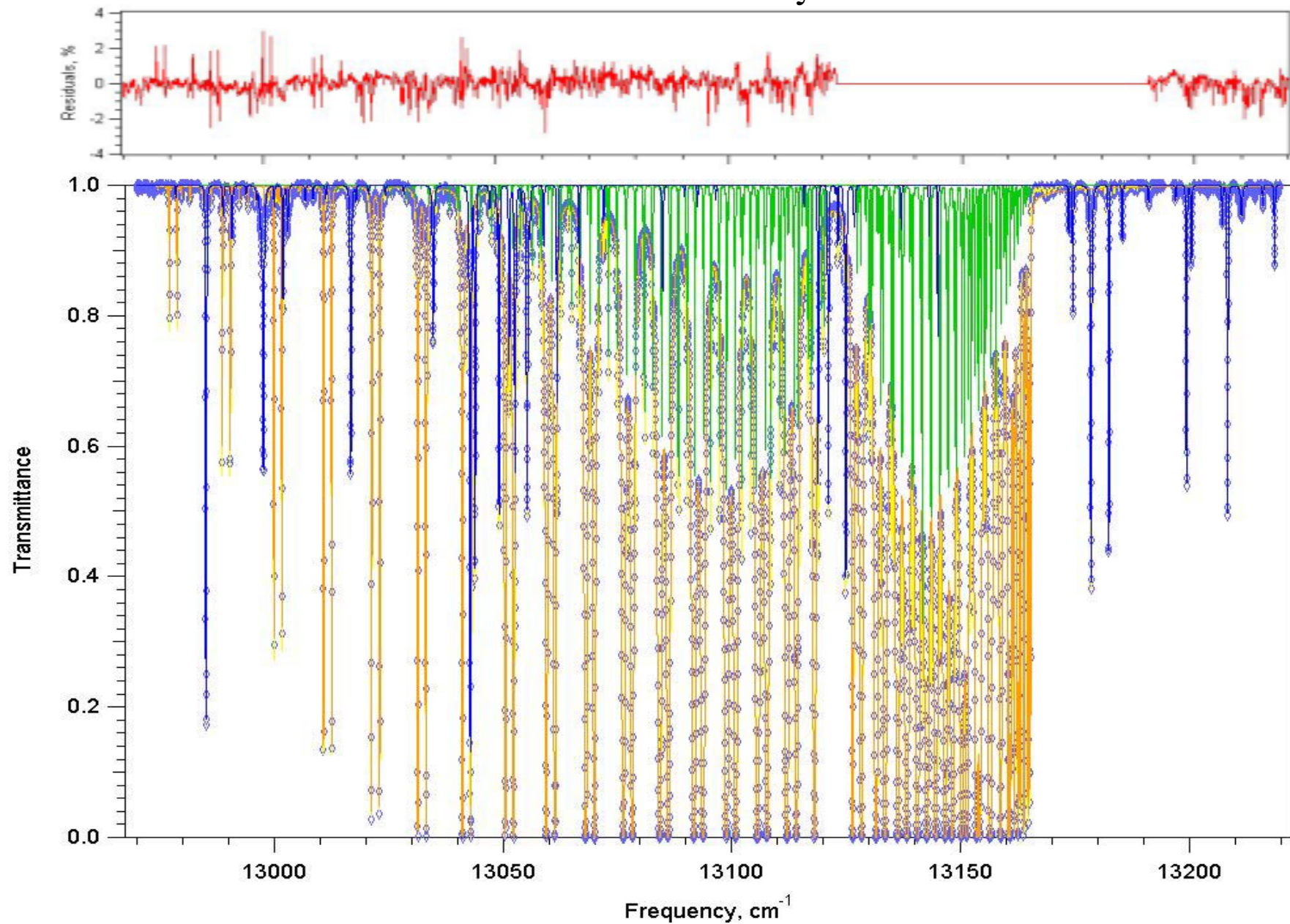
Far-wing lineshape
(continuum)

Line Mixing



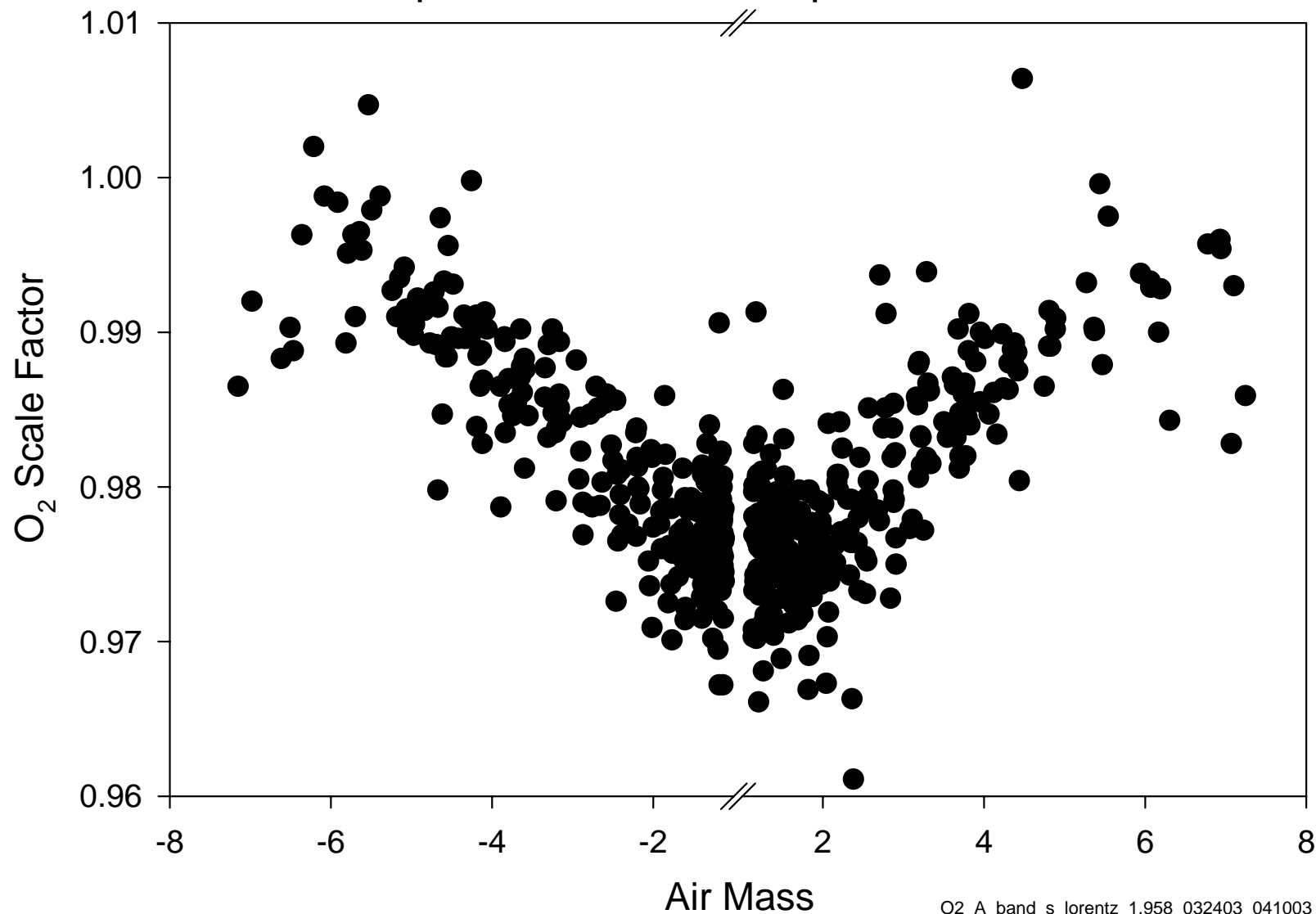
O₂ A-Band Spectrum – TMF/FTUUVS

3/24/03 SZA=42.01° ζ =1.958

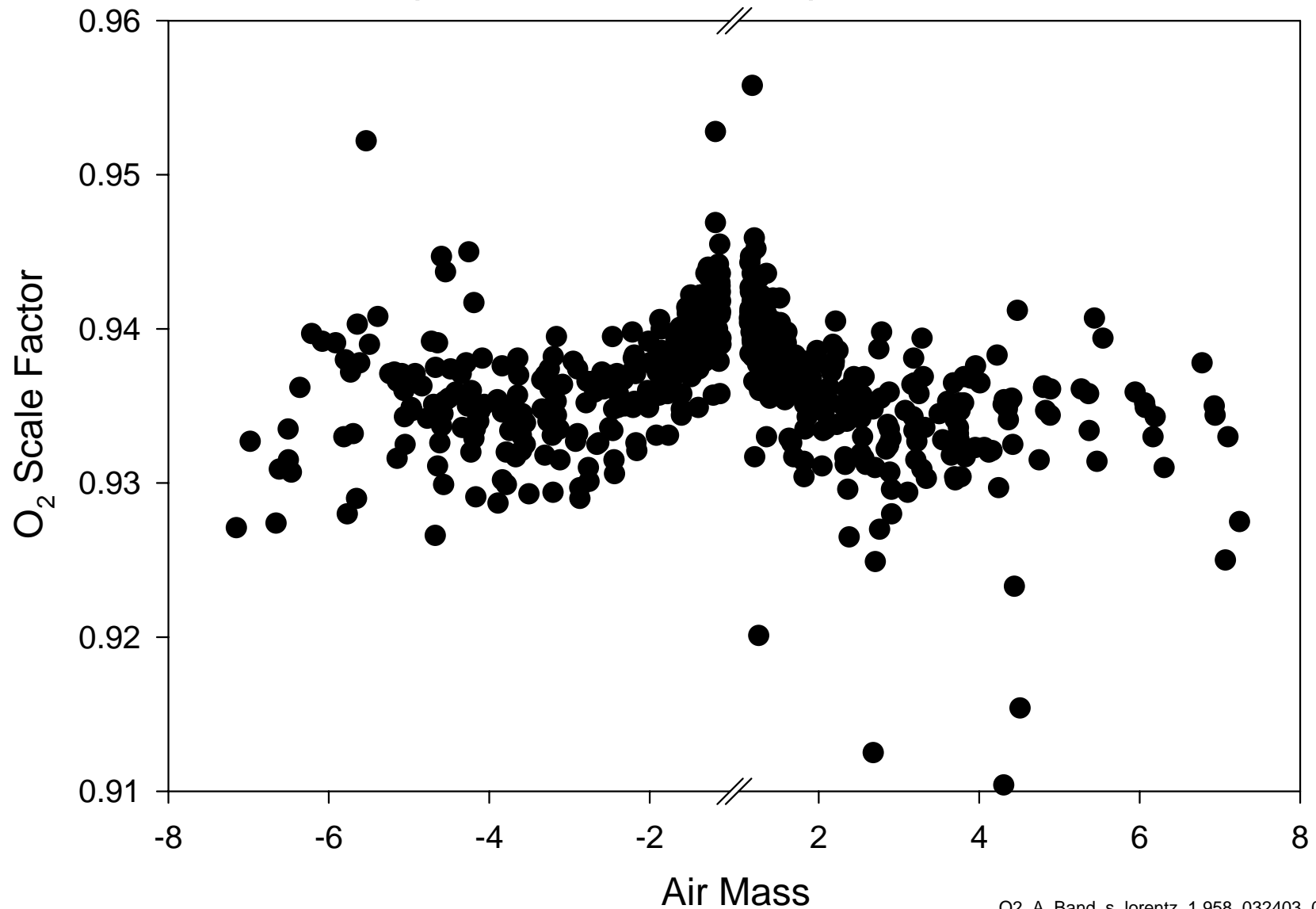


TMF/FTUUVS O₂ A-band: 3/24/03 - 4/10/03

super-Lorentz line shape, eta = 1.977



TMF/FTUVS O₂ A-band: 3/24/03 - 4/10/03
super-Lorentz line shape, eta = 1.958



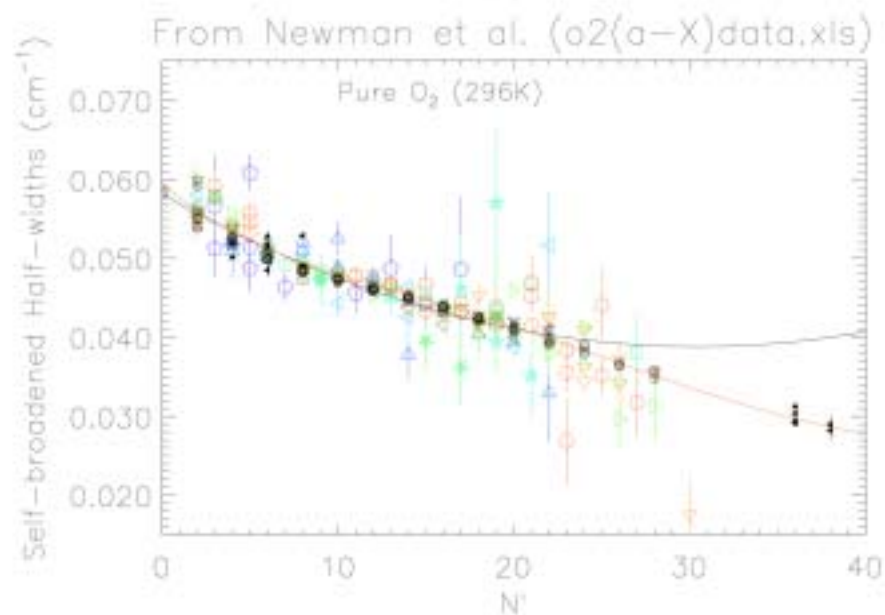
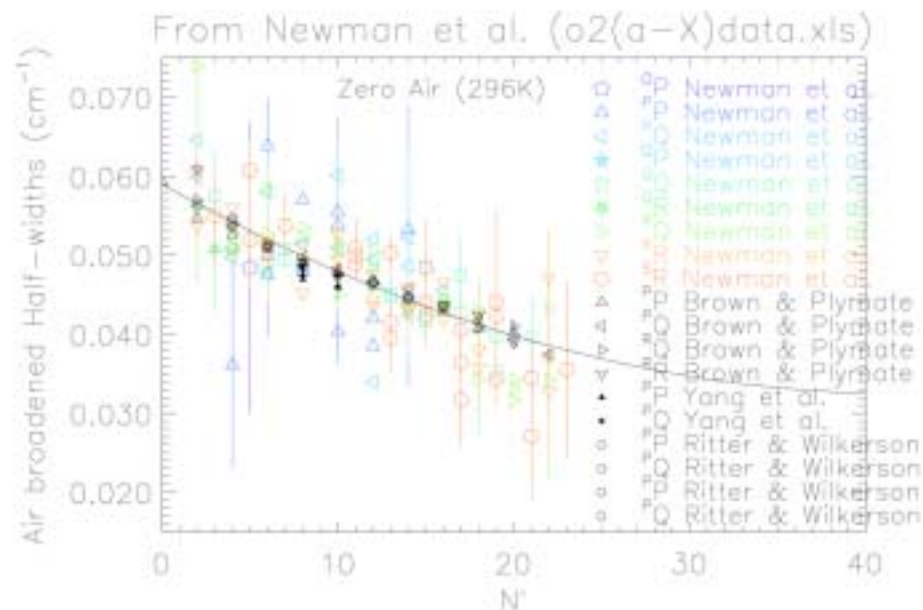
Conclusions

- The O₂ column abundance can be measured with a precision of $\pm 0.3\%$ using ground-based high resolution solar absorption spectroscopy in the A-band.

First retrieval of an atmospheric gas with 0.3% measurement precision.

- Serious spectroscopic issues remain:
 - * Characterization of line mixing
 - * Line shape in the far wings.
 - * Line strengths, air- and self-broadened half-widths esp. at high J.
 - * Spectroscopic parameters for isotopomers.
- Other retrieval issues:
 - * Temperature profile.
 - * Effects of clouds; multiple scattering?

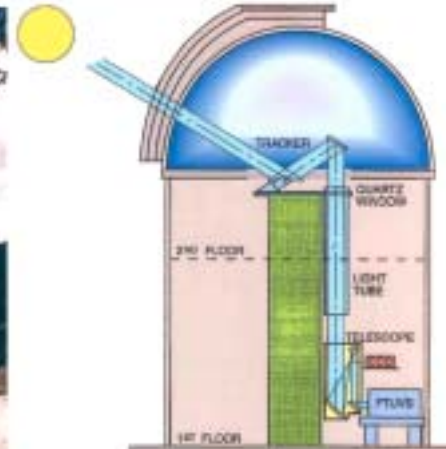
Air and Self-Broadened Half-Widths vs. N' for the O_2 A-Band



FTUVS INSTRUMENT INSTALLATION AT TABLE MOUNTAIN FACILITY



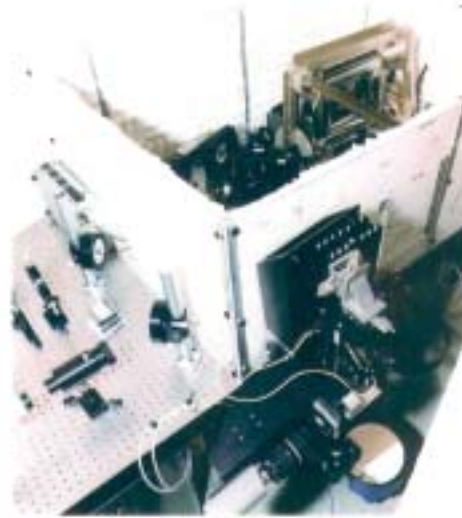
View of the building which houses the FTUVS instrument at JPL's Table Mountain Facility at 7500 ft. elevation near Wrightwood, California.



Layout of the FTUVS facility showing the tracker (heliostat), telescope and FTUVS interferometer.



The FTUVS heliostat showing the 20 in. primary mirror and the 12.6 in. secondary mirror. The secondary can be easily removed from its mounting for zenith sky observations.



View of the FTUVS interferometer (inside the large white box) and the telescope. The telescope achieves a 3:1 magnification of the solar image and has a CCD camera for fine tracking which views the solar image reflected off the field stop.